CHAPTER 4
RECYCLED HOT-MIX ASPHALT CONCRETE

4-1. General.

Recycled hot-mix asphalt concrete should be considered as an alternative anytime a conventional overlay reconstruction is anticipated. Recycling will create a greater savings in material cost and total job cost than that for a conventional overlay or reconstruction on many jobs. Performance of recycled hot mix should be considered equivalent to that expected with conventional hot mix. Recycled hot mix can be used to construct bituminous base, intermediate, and surface courses.

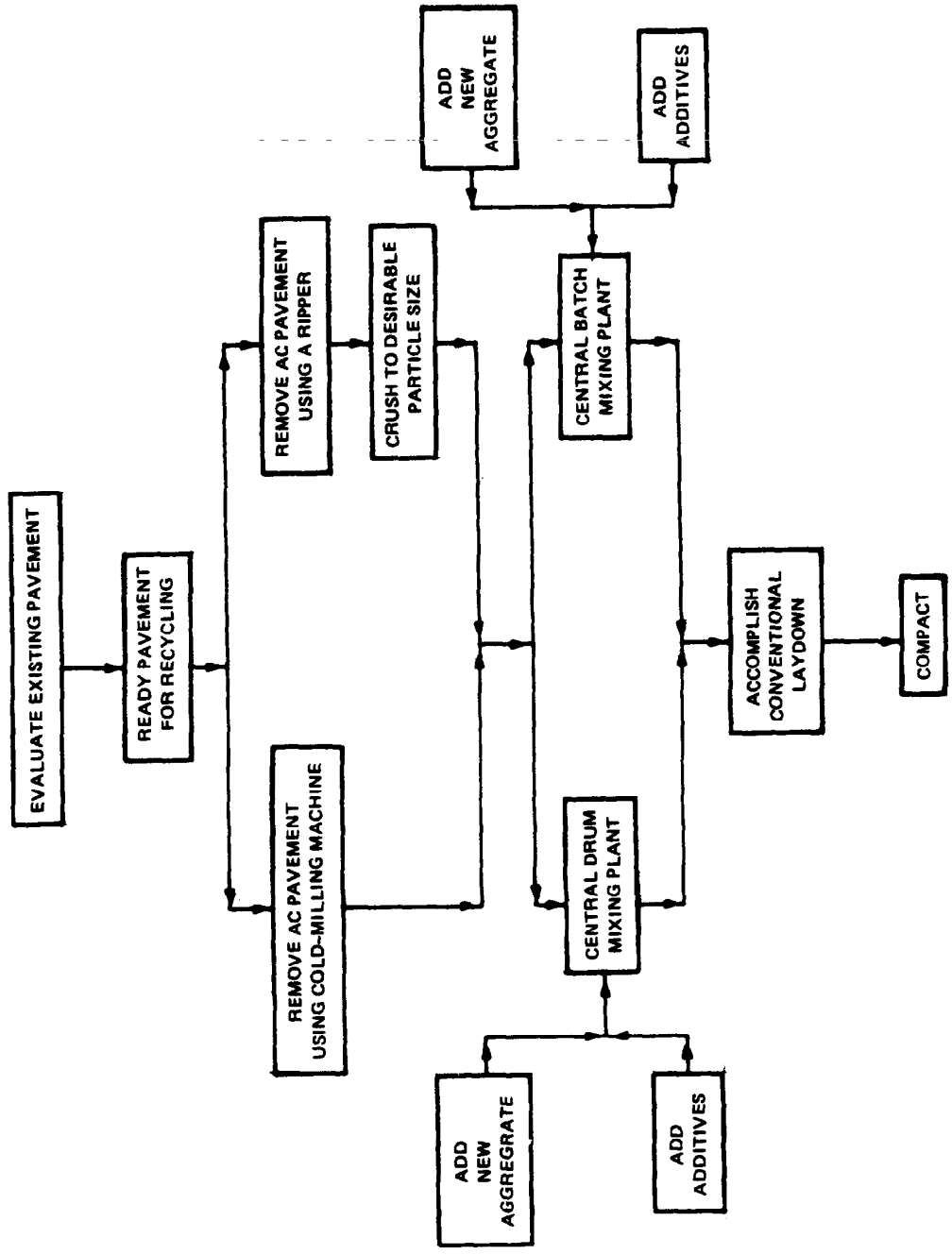

Figure 4-1. Hot recycling process.

4-2. Equipment.

The equipment required for pavement removal and crushing will include either conventional equipment for ripping and crushing or a cold-milling machine. A batch or drum plant, either designed or modified to mix recycled materials is also required. Placement is with a conventional paver, and trucks, front-end loader, and asphalt distributor are also required.

4-3. Recycling hot-mix procedures.

Recycling hot mix consists of removing the existing pavement; crushing the reclaimed mix, if necessary; mixing the reclaimed mix with virgin aggregate, virgin asphalt, and recycling agent; and placing the recycled mix by the same procedures as those used for a conventional mix (fig 4-1).

4-4. Removal and sizing.

The asphalt concrete pavement should be removed by a cold-milling machine or with a ripper tooth and crushed. The cold-milling machine is a self-propelled, power-operated planing machine capable of removing, in one pass, a layer of bituminous material up to 12 feet wide and 2 to 4 inches deep. The equipment should be capable of establishing grade control by referencing from existing pavement or from independent grade control and should have a positive means of controlling transverse slope elevations. The equipment should have an effective means of preventing dust from the operation from escaping into the air. The milled material should pass through a 2-inch sieve. The teeth on the cutting drum must be in satisfactory condition at all times to prevent shearing off chunks of the asphalt concrete and creating oversize particles or a rough surface. If oversize particles are present, they should he removed by screening.

4-5. Virgin aggregates.

Virgin aggregates are added to the recycled hot mix for a number of reasons.

a. Pollution control. Without the addition of new aggregate, air pollution during mix production for most plants would exceed the allowable levels. With the addition of new aggregate, an aggregate shield can be used to prevent the flame from having direct contact with the reclaimed asphalt pavement (RAP) and causing the burning of the asphalt in the reclaimed asphalt pavement, which is the main source of air pollution in hot recycling.

b. Gradation. The gradation of the aggregate in the existing mix can be improved by adding virgin aggregates. Many times existing pavements do not contain the desired aggregate gradation, and if they do contain a satisfactory gradation, it may be changed during the milling or crushing operation. Therefore, the addition of new aggregate allows the gradation of the recycled mix to be modified to an acceptable range.

c. Aggregate quality. Many times the quality of the aggregates in an existing mix is not acceptable, even though the gradation is satisfactory. One cause of poor quality in an aggregate blend is the use of an excessive amount of natural rounded sand. Rounded sand is a poor aggregate for asphalt concrete, but because of its abundance and low cost, it is often used in excess in asphalt concrete mixtures. The addition of a new high-quality aggregate can reduce the percentage of rounded sand in the mixture and thus improve the overall quality of the mix. The amount of natural sand added to a recycled mixture should not exceed 15 percent of the new aggregate for airfields.

d. Excess filler material. Existing asphalt concrete pavements were generally constructed with the amount of filler material passing the No.200 sieve near or above the maximum allowed by specifications. The amount of filler in the reclaimed mixture most often varies between 8 and 12 percent whereas the maximum amount of filler allowed is 6 percent. During the milling or crushing operation approximately 1 to 3 percent additional filler will be manufactured. Thus, in order to control the amount of filler, the new aggregates must be limited to very little or no filler. The virgin aggregates may have to be washed to minimize the amount of filler material. In addition, the percent of virgin aggregate in the recycled mixture may have to be adjusted to help control the filler content.

e. Asphalt binder. The asphalt binder in existing pavement is usually oxidized and requires some modification during recycling to produce an acceptable asphalt binder and mixture. If no new aggregate is added to the mix, the addition of asphalt or recycling agent needed to produce satisfactory asphalt cement properties may result in a mixture that is too rich. The asphalt cement content of the existing pavement mixture is generally near the optimum asphalt content; hence, the addition of more asphalt cement or recycling agent may result in an excessive asphalt content. If the existing asphalt binder is not modified with a low viscosity asphalt or recycling agent, a brittle mixture will be produced.

4-6. Mix design.

The mix design is conducted to determine the percentages of reclaimed asphalt mixture, each new aggregate, recycling agent, and asphalt cement to be used in the mixture. The amount of reclaimed mixture used in a recycled mixture is usually based on the amount of reclaimed materials available, the desired physical properties of the recycled mix, requirements of the aggregate gradation, economical considerations, and the type of asphalt plant. A drum mixer can prepare recycled asphalt mixtures using up to a maximum of 70 percent reclaimed mixture. However, in order to ensure that the quality of the mix is controlled, the amount of reclaimed asphalt concrete used in the production of recycled hot mix should not exceed 60 percent. When a modified batch plant is used to produce the recycled mixture, the maximum amount of reclaimed materials that can be added to the mixture generally varies between 50 and 60 percent because at least 40 to 50 percent new superheated aggregate is needed to obtain sufficient heat transfer to the reclaimed asphalt pavement material. The selection and evaluation criteria for the new and old aggregate are the same as those for new hot mixes.

a. Percentage of aggregate. The first step in the mixture design is to determine the percentage of each new aggregate and reclaimed asphalt concrete that should be used. The amount of reclaimed asphalt concrete that can be practically recycled is determined, as discussed in paragraph 4-6. The gradation of the aggregate extracted from the reclaimed asphalt and the gradations of the new aggregates are then determined. The percentage of each aggregate to be used in the recycled mixture is then selected so that the blended gradation of all aggregates used, including the aggregate in the reclaimed asphalt concrete, meets the specification requirements.

b. Type of binder. The second step is to determine the type of binder or recycling agent to be used in the mixture. A recycling agent is usually required to modify the oxidized asphalt binder. When the penetration of the old asphalt binder is more than 10 percent and the amount of reclaimed asphalt concrete used in the recycled mixture is below 50 percent, the existing asphalt binder can usually be modified with an asphalt cement such as AC-2.5 (ASTM D3381). In this case, no recycling agent would be needed. When the amount of reclaimed asphalt concrete used in the mixture exceeds 50 percent, or when the penetration of the existing asphalt binder is less than 10 percent, a recycling agent is generally needed. For many jobs it will be necessary to use an asphalt cement and a recycling agent to properly modify the existing asphalt at optimum asphalt content.

c. Preparation. The third step consists of preparing recycled mixtures at various asphalt contents with 0, 0.5, and 1.0 percent recycling agent, if a recycling agent is being used. The following data should be plotted for each recycling agent content being evaluated: (1) density versus additional asphalt content, (2) stability versus additional asphalt content, (3) flow versus additional asphalt content, (4) voids in the total mix versus additional asphalt content, and (5) voids filled with asphalt versus additional asphalt content. These graphs, with the exception of stability, take the same shape as those developed when conducting a mix design for conventional hot-mix asphalt concrete. The plot of stability versus additional asphalt content generally indicates the highest stability at 0 percent additional asphalt and a reduction in stability as the asphalt content is increased. The optimum asphalt content should be determined by averaging the asphalt contents at the peak of the density curve, middle of the voids in the total mixture requirements, and middle of the voids filled with asphalt requirements. The requirements for voids in the total mix, voids filled with asphalt, stability, and flow are the same as those for conventional hot-mix asphalt concrete. Mixtures at optimum asphalt content for each recycling agent content should be prepared and the asphalt recovered from these mixtures. The penetration of the recovered asphalt should be a minimum of 60 percent of the desired original asphalt penetration for the area in which the mixture is to be used. The amount of recycling agent should be selected so that the recovered asphalt penetration meets the desired limits. It is important that the penetration of the recovered asphalt be measured during plant production and that adjustments be made if necessary to ensure proper asphalt consistency. Paragraph B-2 gives a design example of a hot-mix design for a recycled asphalt concrete pavement.

4-7. Recycling hot-mix quality control.

Most recycled asphalt concrete is produced with a drum mixer designed or modified to produce recycled mixtures. Modified batch plants have also been used successfully to produce recycled hot mix.

a. Drum mixer. when a drum mixer is used for recycling, the new aggregate is added at the high side of the drum near the flame (fig 4-2). The aggregate absorbs much of the heat from the burner and acts as a shield to protect the reclaimed asphalt concrete, new asphalt binder, and recycling agent. The reclaimed asphalt concrete is added to the drum near the midpoint followed by the recycling agent and new asphalt. The flights inside the drum should be in good condition

so that the veil of new aggregate will properly protect the asphalt materials from heat damage. The final recycled mixture is generally heated to between 260 and 290 degrees F to produce a mixture that can be compacted to meet density requirements. Pollution is sometimes a problem, but generally the mix design can be modified by lowering the percent of reclaimed asphalt pavement to bring pollution within an acceptable range.

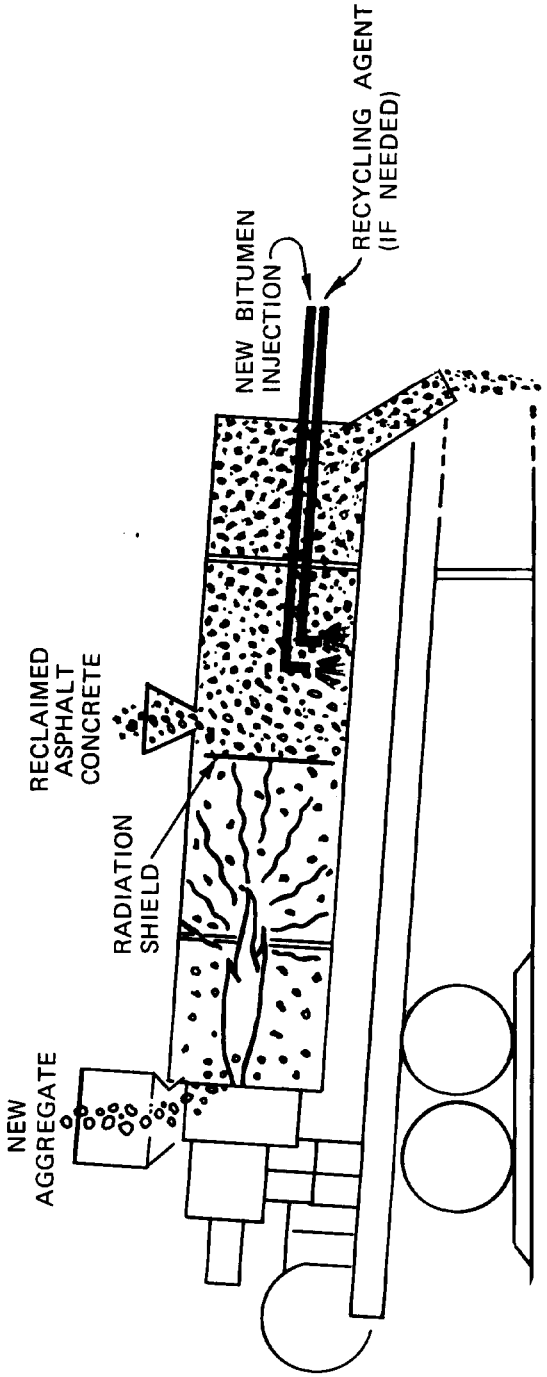

Figure 4-2. Recycling hot-mix production in a drum mixer.

b. Batch plant. Batch plants have also been modified so that recycled mixtures can be produced (fig 4-3). The modification consists of adding a feeder and conveyor to carry the reclaimed asphalt pavement directly to the weigh bucket. The new aggregate that passes through the dryer is usually superheated to between 500 and 600 degrees F so that when the materials are blended, the resulting temperature is suitable for mixing and compaction. An increase in the amount of reclaimed asphalt concrete used in the mix would require an increase in the new aggregate temperature. Also, additional moisture in the new aggregate or reclaimed asphalt pavement stockpiles will require additional heat. Therefore, to save energy both stockpiles should be kept as dry as possible,

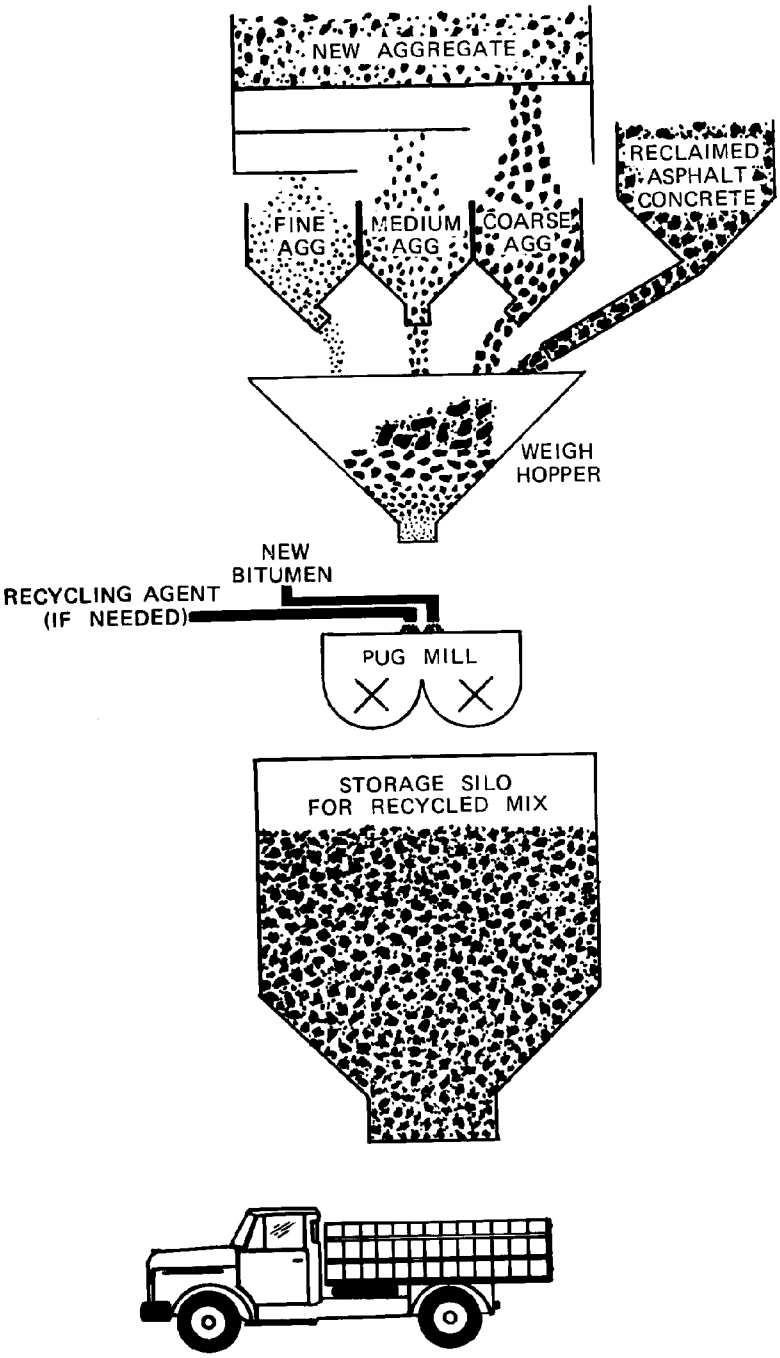

Figure 4-3. Recycling hot-mix production in a batch plant.

c. Stockpiling. Prior to production of recycled asphalt concrete, the stockpile of reclaimed materials should be inspected to ensure that no significant segregation of material exists. Many pavements have been patched during their lives causing variation in the type of materials at various locations in the pavements. Therefore, the materials should be removed from the pavement and stockpiled in such a way to ensure proper mixing of these localized materials with the other reclaimed materials. When the asphalt pavement is removed in two lifts, the properties of the material in the top lift will probably vary from the properties of the materials in the bottom lift. In this case, the materials should be stockpiled separately, or some acceptable procedure for blending these materials must be used.

d. Cold feeds. In order to remove all material larger than 2 inches a screen should be placed over the bin or cold feeder from which the reclaimed materials will be fed to the plant. when conglomerations of asphalt and aggregate exceed this size, they will not break down enough in the asphalt plant to produce a homogeneous mixture. Consequently, these oversize pieces may cause problems with pulling and tearing of the mat during the lay- down operation.

e. Control testing. During production of recycled asphalt concrete, a number of tests must be conducted to ensure that a satisfactory product is produced. The tests used to evaluate recycled mixtures are the same tests used to evaluate conventional hot mix. These tests evaluate material properties such as, Marshall stability, flow, laboratory density, voids in the total mixture, voids filled with asphalt, aggregate gradation, asphalt content, temperature, and field density. Penetration of the recovered asphalt cement is another property that is needed to evaluate recycled mixtures during production.

4-8. Laydown of recycled hot mix.

There should be no difference between the laydown of recycled hot mix and the laydown of conventional hot mix. The recycled mixture may appear to be a little more oily, which is probably due to recycling agent, but this condition is normal.

4-9. Excess reclaimed asphalt pavement.

All excess reclaimed asphalt pavement should be stockpiled for use on other Government projects. If the ownership of excess reclaimed asphalt pavement is transferred to the contractor, credit should be given to the Government for its value.